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The impact of the hierarchical medical system on medical resource allocation in China

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The disparity in medical resource distribution across regions poses a significant challenge to healthcare reform in China. To address this, China has introduced the hierarchical medical system (HMS). This study evaluates the HMS's impact on the equitable distribution of medical resources. We employ the Theil index to quantify the equalization of resources among cities within provinces and use a multi-period difference-in-differences model to assess the HMS's influence. Our findings indicate that the HMS has significantly contributed to the equal distribution of medical material resources, although its effect on medical human resources is less pronounced. Additionally, we explore the influencing factors of the HMS from the perspective of supply and demand and find that it is more effective in areas with abundant resources and high demand for high-level medical services. More importantly, the HMS has played an important role in mitigating medical disparities in regions with unbalanced economic statuses. These insights are instrumental for policymakers, guiding the evolution of healthcare reforms and the refinement of the HMS to achieve the objective of universal health coverage.

Keywords Hierarchical medical system, Medical resources, Equalization, Difference-in-differences, China

In the past four decades, China has experienced a substantial expansion in its medical resources. Specifically, from 1978 to 2023, the bed capacity in healthcare institutions per 1000 individuals has increased from 2.1 to 7.23, while the number of licensed (assistant) doctors per 1000 individuals has increased from 1.08 to 3.40. These increases suggest that China is nearing the doctor-to-population ratios observed in many developed countries, and in terms of bed availability, it even surpasses some of these nations. Despite this progress, the allocation of medical resources in China has historically been restricted by public budgetary constraints[1], leading to an emphasis on efficiency and a concentration of resources in economically developed regions, including provincial capitals, regional centers, and major cities. In the spatial distribution of medical resources, GDP strongly correlates with the supply of medical resources in China, whereas demographic factors show weak correlations[2]. This concentration results in substantial patient migration across regions[3], which in turn puts immense pressure on medical resource hubs[4] and increases the expense of medical services[5]. The uneven distribution of medical resources has also contributed to disparities in medical utilization[6] and health outcomes[7–10]. "It is difficult and expensive to see a doctor" (commonly known as *kan-bing-nan*, *kan-bing-gui* in Chinese) has become a significant problem that runs counter to the goal of universal health coverage[11]. Prioritizing the geographic balance and coordination of medical resources is essential for reforming China's medical system[12].

Faced with the increasingly severe issue of *kan-bing-nan* and *kan-bing-gui*, China took a significant step in March 2009 by issuing the "Opinions of the CPC Central Committee and the State Council on Deepening the Health Care System Reform," commonly referred to as the new healthcare reform[13]. This reform aims to strengthen the government's financial commitment to healthcare and is a crucial component of the China's efforts to address the challenges in the medical sector[14,15]. A key aspect of the new healthcare reform is the establishment of the hierarchical medical system (HMS). One of the primary goals of the HMS is to ensure that residents can receive treatment for serious illnesses within their province, minor ailments within their county, and routine conditions at the township level. Therefore, on the supply side of medical resources, the HMS focuses on promoting the decentralization of medical resources to ensure a balanced regional layout and also strictly regulates the uncontrolled growth of large healthcare facilities[16]. The central government encouraged all localities to carry out practice innovation of the HMS since 2009. However, no specific HMS policies were implemented initially. Until 2012, several provinces explored the HMS as pilots. Although the HMS has been in place for a long time, its effects are still not well understood.

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Research on the implementation effect of the HMS in China is limited, primarily focusing on patients' health-seeking behavior and medical resource utilization. Zhou et al.[17] find that while the HMS has successfully steered urban residents towards primary care facilities for initial consultations, its impact in rural regions has been less pronounced. The HMS combined with the online appointment diagnosis system has shown promise in improving patient distribution across various healthcare facilities[18]. However, the effectiveness of such technological integration may depend on factors like internet accessibility and digital literacy. Some studies have examined the impact of the HMS in a single pilot area. Evidence from Yinzhou district, Ningbo, the HMS redirected patient flows to primary care facilities and promoted the centrality of primary care doctors within their professional network, suggesting improved coordination and integration of care for patients with hypertension[19]. A study in Shanghai showed the short-term benefits of the HMS on medical performance in central districts and indicated spatial variation in its impact[20]. Wu et al.[21] evaluated the operational efficiency of the HMS in primary medical and health institutions in Fujian Province and found the redundancy rate was generally high. Few studies pay attention to the effect of the HMS on the supply side. Although Lu et al.[22] take Beijing as an example to analyze the impact of the HMS on the fairness and spatial accessibility of medical resources, their study is limited to observations within a single pilot city, which lacks extensive investigation into the broader implications of the HMS.

This paper evaluates the pilot of the HMS implemented at the provincial level, intending to provide policy implications for further implementation in China. First, the Theil index measures the equalization level between cities in each province. Second, to observe whether the policy has promoted equalization, the difference-in-differences(DID) model is used to evaluate the changes after implementing the HMS. The results indicate that the HMS has had a significant positive effect on equalizing the medical material resources supply between cities in the province. However, the equalization effect of medical human resources in the province is insignificant. After conducting the parallel trend test and placebo tests, and replacing different equalization measurement methods, the above main findings remain robust. Third, we discuss the impact of the HMS on resource allocation from the perspective of supply and demand and find that the effect of the HMS on promoting equalization is stronger in areas with the high supply of medical resources and high demand for high-level medical resources. At the same time, we investigate the impact of the HMS on medical resource allocation under economic inequality and find that the HMS promoted the equalization of medical resource allocation in areas with unequal economic development.

There are three marginal contributions in this paper. First, our knowledge indicates that even though a few studies explored the effect of the HMS on the medical demand side, the impact of the HMS on the medical supply side has not yet been investigated. Second, we first use a rigorous empirical strategy to investigate the impact of the HMS on equalizing medical resources, which is instructive for thinking about how to improve the HMS from the supply side further to promote fairness. Third, we discuss the role of high supply and high-level hospital demand in promoting the equalization of medical resources and the possibility of the HMS breaking the economic constraints of medical resource equalization. What role the government should play in realizing the equalization of medical services is an essential issue in health economics and public management. The policy practice in China and this study may also benefit the field's growth.

Conceptual framework

In 1978, China embarked on market-oriented reforms, transitioning its economy from a centrally planned system to one driven by market dynamics[23]. These reforms dismantled egalitarian policies that had previously ensured the equal distribution of resources across the nation[24]. Although the primary objective of the reforms was to stimulate economic growth and development, they inadvertently altered the distribution of resources within the healthcare sector. The marketization of the economy spurred rapid growth and expansion in the medical sector, which was initially perceived as a positive outcome. However, this expansion was not uniformly distributed. It led to a concentration of medical resources in economically prosperous regions, resulting in a relative scarcity of medical facilities and professionals in less developed areas[1].

The implementation of the HMS has solidified the government's primary responsibility in medical resource allocation and promoting equitable access to medical services[25,26]. The central government has delegated decision-making and management authority to provincial levels, guiding policy execution while allowing regional customization. This decentralization, coupled with provincial autonomy, ensures that HMS policies are tailored to local conditions, thereby enhancing the efficiency and relevance of healthcare delivery. By setting clear standards and expectations, the central government ensures that the pilot programs are implemented effectively and that the benefits of the HMS are realized across the country.

Firstly, the HMS reinforces the responsibility of governments at all levels, on the guiding and constraining role in resource allocation. Local governments are tasked with developing and implementing healthcare service plans based on provincial guidelines and resource standards, ensuring a rational layout and efficient operation of the healthcare system. This includes the establishment of medical institutions through government funding or service procurement, and the rational division of service areas, with a focus on strengthening the basic medical service capabilities of township health centers. Additionally, the program encourages private medical practice by simplifying the approval process for individual clinics, enabling doctors to provide services in their communities.

Secondly, the HMS addresses the gap in resources in less developed areas by adhering to the principle of "filling the gaps." It focuses on enhancing the clinical specialty capabilities of county-level public hospitals, particularly in treating common and prevalent diseases, and appropriately relaxes restrictions on medical technology applications to improve the overall service capacity of these hospitals. The HMS also streamlines the mobility and training of medical personnel by strategically rotating urban doctors to grassroots institutions and vice versa, fostering an environment for continuous learning and skill development. This approach facilitates the transfer of high-quality medical professionals from larger hospitals to other regions, ensuring a more balanced distribution of expertise. The national evaluation criteria for the pilot program require that counties with populations of over 300,000 have at least one secondary-level general hospital and one secondary-level traditional Chinese medicine hospital, with an in-county treatment rate of around 90%, essentially ensuring that major illnesses can be treated within the county.

Thirdly, the HMS controls the irrational expansion of individual public medical institution scales. It focuses on limiting the number and size of tertiary hospitals and establishing a bed control mechanism centered on disease structure, service coverage, task completion, talent training, and work efficiency. This strict control over hospital bed expansion ensures that the growth of public hospitals is aligned with the needs and capabilities of the healthcare system, preventing overexpansion and maintaining a balanced distribution of medical resources.

Hypothesis 1 The implementation of the HMS has led to more balanced medical resource allocation among cities in the province.

An important factor affecting the equalization of medical resources for the HMS is the total supply of medical resources. In provinces with abundant medical resources, there are typically more medical institutions, healthcare professionals (such as doctors and nurses), as well as better-equipped facilities, and advanced technologies. In such cases, implementing the HMS can effectively utilize these resources, improve the efficiency and quality of healthcare services, and better meet the needs of patients. Next, provinces with abundant medical resources often have well-established multi-level healthcare service networks that cover various levels of medical institutions, ranging from primary to advanced care. These networks provide a solid foundation for the implementation of the HMS, enabling smooth patient referrals and appropriate medical services[27]. Moreover, provinces with abundant medical resources usually have strong economic capabilities, which can better support the implementation of the HMS. Investing in the enhancement of service capabilities, and introduction of advanced technologies and equipment at primary healthcare institutions is required for the HMS. Provinces with abundant medical resources are more likely to bear these costs and provide robust support for the promotion and operation of the HMS.

Hypothesis 2 Provinces with abundant medical resources are more capable of promoting medical resource equalization after the HMS.

Another important factor affecting the equalization of medical resources for the HMS is the intensity of patient demand. Patients tend to concentrate their visits to higher-level medical institutions when there is a high demand for quality medical resources. This means that these advanced medical institutions may become overloaded with medical tasks, while resources at the primary institutions may be underutilized, resulting in an excessive concentration of resources and an imbalance in resource utilization[28]. In provinces facing more intensity of medical tasks in high-level medical institutions, the HMS allows for a more balanced allocation of resources across different levels of medical institutions through classification and patient referral, which helps alleviate the burden on higher-level medical institutions. Therefore, provinces with a high demand for quality medical resources are more motivated to optimize the distribution of medical resources may lead to better promotion of equalization.

Hypothesis 3 Provinces with a high demand for quality medical resources are more motivated to promote medical resource equalization after the HMS.

Economic development is the material basis for providing basic medical services[1,29]. In China, due to the imbalanced economic development, the difference in financial income capacity at all levels, and the difference in medical input cost, the imbalanced supply of primary medical services in China has been prominent for a long time. In other words, the more imbalanced the regional economic development is, the more unequal the allocation of medical resources will be. By strengthening the construction of primary medical institutions and improving their service capacity, the HMS enables residents in economically underdeveloped areas to obtain basic medical services nearby. Hence, we propose the following hypothesis:

Hypothesis 4 The HMS can mitigate the inequality of medical resource supply caused by economic imbalance.

In summary, the HMS enhances government accountability, addresses resource deficiencies in underdeveloped regions, and regulates the growth of public hospitals, all with the goal of fostering a more equitable medical resource allocation. Moreover, the equalization effect of the HMS may be influenced by supply abundance, demand intensity, and economic imbalance. We developed our conceptual framework and summarized it in Fig. 1.

Methodology and data

Explained variable

The number of beds is employed as a proxy for medical material resources. The quantity of beds is one of the key indicators for assessing the scale and capacity of medical institutions[3]. A higher number of beds signifies that a medical institution can accommodate a larger number of patients simultaneously, thereby offering a greater volume of medical services. The number of beds in this study differs from inpatient beds, encompassing a broader range and adhering to a fixed statistical methodology in China. According to the bed count statistical criteria published by the National Bureau of Statistics of China[30], the scope of bed count statistics for medical institutions includes public hospitals and private hospitals; health clinics; maternal and child health institutions;

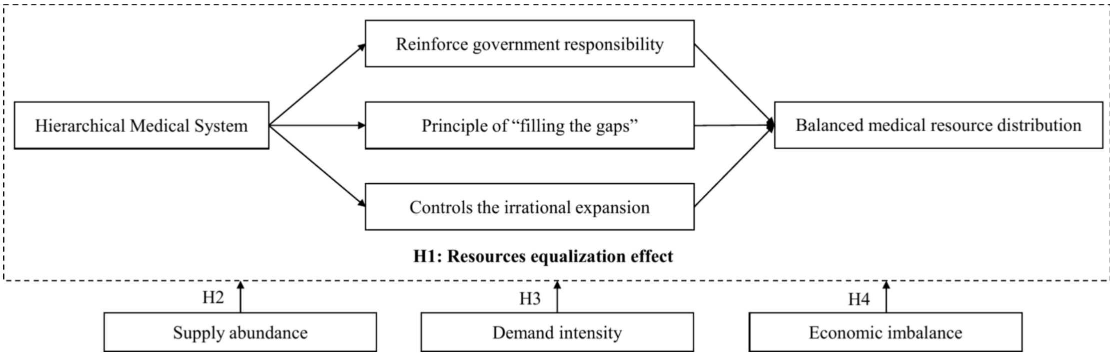

Fig. 1. Conceptual framework.

specialized disease prevention and treatment institutions; and community health service institutions. This refers to the fixed and actual number of beds in medical institutions, including regular beds, simple beds, intensive care beds, additional beds for more than half a year, beds undergoing disinfection and repair, and beds damaged due to recent or major renovations. It does not include beds for newborns in obstetrics, beds for labor in delivery rooms, beds in storage, observation beds, temporary additional beds, and some beds for patient companions.

Additionally, the number of licensed (assistant) doctors is employed as a proxy for medical human resources. Licensed (assistant) doctors refer to medical workers who have obtained the licenses of qualified (assistant) doctors and are employed in medical treatment, disease prevention, or healthcare institutions, excluding those licensed doctors engaged in management positions. Licensed doctors are categorized into four groups: clinicians, Chinese medicine physicians, dentists, and public health physicians[30]. The registration of doctors refers to the assessment of whether doctors have industry qualifications, which are uniformly issued by the National Health Commission with a nationally standardized entry threshold and must be registered in a standardized manner within medical institutions. Only after obtaining the licenses of qualified doctors and being granted the corresponding prescription rights in the registered medical institution can they prescribe for patients in clinical activities. Previous studies using the same dimension as ours also represent the richness of medical human resources with the licensed (assistant) doctors[8,12].

There are many methods to measure the degree of equalization, mainly including the Theil index method, coefficient of variation method, Gini coefficient method, and concentration index[6]. The Theil index, based on entropy from information theory, is a classic tool for measuring income inequality and has been used to assess disparities across regions. The decomposable nature of the Theil index and its sensitivity to the changes of upper and lower layers, and then widely used to study overall regional differences and regional differences in medical resources[31,32]. In the traditional sense, the Theil index is weighted by GDP or resource quantity, called the Theil-T index; another form of generalized entropy index, weighted by the proportion of the population, is called the Theil-L index. The Theil-T index is sensitive to the change in upper income, while the Theil-L index is sensitive to the change in lower income. In the baseline regression model, the Theil-T index is considered the main measurement index of the equalization of medical resource supply in each province. The Theil-L index and coefficient of variation are used as the robustness test.

From the perspective of medical resource allocation, existing studies generally examine the equalization of the medical resource supply side from three aspects: human, material, and financial resources. The direct output of the government's financial investment in medical and health undertakings is the increase of medical human and material resources. Considering data availability, this study only analyzes the equalization level of medical human resources and material resources in China. The formula for calculating the Theil-T index between cities in the province is set as follows:

$$Theil_i^T = \sum_j^N \left(\frac{Y_{ij}}{Y_i}\right) \log\left(\frac{Y_{ij}}{Y_i} \Big/ \frac{P_{ij}}{P_i}\right) \tag{1}$$

where Y_{ij} denotes the medical resource supply of the city j in the province i, and Y_i denotes the medical resource supply of the province i. P_{ij} is the population of the city j in the province i, and P_i is the population of the province i.

The range of the Theil index is from 0 to 1. When the Theil index equals 0, this region's medical resource allocation is absolute fairness. The closer the Theil index is to 1, the more imbalanced medical resource allocation is in this region.

Core explanatory variable

We searched the official website of the provincial government and the official website of the Department of Health and Health Commission, with "Hierarchical Medical System" as the core keyword, supplemented by the same keyword in the Peking University Law's Local Laws and Regulations Database. When the policy document first proposes "the establishment of the HMS" in the province, we consider that time point to be the beginning of the establishment of the HMS in that province. Furthermore, if documents are released in the first half of the year, they are presumed to be implemented within the same year. Conversely, documents released in the second half of the year are assumed to be implemented in the subsequent year. Additionally, the documents issued by pilot provinces regard the construction of the HMS as a lasting task, and there is no situation in which provinces withdraw after the pilot.

Empirical strategy

To evaluate the impact of the HMS on equalization, we apply the DID strategy with two-way fixed effects (TWFE). As the HMS is implemented by region and year by year, referring to the research design of Beck et al.[33], the DID model with multiple periods is adopted to estimate the implementation effect of the HMS, and the following econometric regression model is specifically set:

$$Y_{it} = \beta_0 + \beta^{did} HMS_{it} + \lambda Control_{it} + v_i + \mu_t + \varepsilon_{it} \tag{2}$$

where Y_{it} denotes the equalization of the medical resource supply of the province i in year t. The key independent variable, HMS_i, is a dummy variable for the province i treatment status. If the province i implements HMS in year t, then HMS_i takes the value 1 for the city in year t and later, and 0 for the year before. $Control_{it}$ is a set of control variables. v_i is province fixed effects, μ_t is year fixed effects and ε_{it} is random error term.

The important premise of the DID is to satisfy the parallel trend assumption, that is, there is no significant difference between the experimental group and the control group before the HMS. To test the parallel trend of DID with multiple periods, refer to the event study method and then set up the following model:

$$Y_{it} = \alpha_0 + \sum_{k \geq -5, k \neq -1}^{5} \alpha_k D_{it}^k + \lambda Control_{it} + v_i + \mu_t + \varepsilon_{it} \tag{3}$$

In the formula (3), D_{it}^k is a set of dummy variables representing an event dummy variable for a specific period. Assumed that the implementation time point of the HMS owned by the province is $year_i$, let $k = t - year_{it}$, when $k \leq -5$, $D_{it}^{-5} = 1$, otherwise it is 0; when $k = -5, -4, \ldots, -2, 0, 1, \ldots, 4, 5$, and $D_{it}^k = 1$, otherwise it is 0; when $k \geq -5$, $D_{it}^k = 1$, otherwise it is 0. In this study, $k = -1$ is used as the base period. For the specific calculation, the term D_{it}^{-1} in formula (3) will be removed. By comparing the significance of the estimated coefficients α_k when $k \leq -2$, we can judge whether it satisfies the parallel trend assumption. If the coefficients, α_k, are not significant, it means that there is no significant difference between the experimental group and the control group in the trend of the equalization of medical resource supply before the HMS, and the parallel trend assumption holds. In addition, when $k \geq 0$, we can also test the dynamic effect of the HMS by observing the significance of the coefficients α_k, that is, observe whether the effect of the HMS changes in the year when the HMS is implemented and in the following years. We incorporate a series of time-varying covariates, $Control_{it}$, at the provincial level as control variables, aiming to isolate the net effect of policy implementation. First, considering the significant differences in economic development levels among provinces, which may directly affect the allocation of medical resources[34], we introduced the Theil index calculated based on GDP disparities to reflect the imbalance of economic development. Second, to account for the impact of unbalanced consumption capacity, we employed the Theil index of the total retail sales of consumer goods as an indicator, as consumption levels in different areas reflect the quality of life and medical service demands of local residents[6]. Third, with the development of information technology and its changes to the way health information is accessed[35,36], we also took into account the gap in information acquisition between cities, quantifying it through the Theil index of information disparities based on the number of Internet users. Additionally, the Theil index is between 0 and 1, we employed the panel Tobit model as a robustness check.

Data description

The data were drawn from the China City Statistical Yearbook from 2010 to 2019. When calculating the Theil index between cities in each province, we made use of the number of beds and the number of licensed (assistant) doctors in medical and health institutions at the city (whole city) level in the China City Statistical Yearbook of each city over the years, and the missing values of some years' data at the city level were filled up by linear interpolation, and finally, the inter-city equalization level of 23 provinces was obtained. Table 1 shows the descriptive statistical results.

Results

The results of the Theil index

Table 2 presents Theil indices for the distribution of medical resources, across various provinces in China for the years 2010 and 2019. The Theil index measures inequality, with lower values indicating more equitable distribution. The overall trend shows that most provinces experienced a decrease in the Theil index for beds from 2010 to 2019, indicating a more balanced distribution of medical material resources over this period. Similarly, the Theil index for the number of licensed (assistant) doctors generally decreased across most provinces, reflecting improved equity in medical human resources distribution from 2010 to 2019.

Table 2 reveals considerable disparities in the equity of medical resource distribution among different provinces. For example, in 2019, Guangdong Province had a Theil index of 0.1709 for beds, whereas Zhejiang Province had a much lower index of 0.0410, indicating more equitable distribution in Zhejiang. Most provinces have shown improvements in the equitable distribution of medical resources between 2010 and 2019, suggesting a nationwide trend toward more balanced medical resource allocation.

Variables	Meanings of the variables	N	Mean	SD
Bed_bc	Theil index between cities for bed	230	0.050	0.036
Doc_bc	Theil index between cities for licensed (assistant) doctors	230	0.076	0.065
HMS	Policy indicator of hierarchical medical system	230	0.500	0.501
TGDP	Theil index between cities for GDP	230	0.163	0.105
TCONS	Theil index between cities for consumption capacity	230	0.184	0.103
TINF	Theil index between cities for information	230	0.141	0.126

Table 1. Summary statistics. The 23 provinces are Hubei, Guangdong, Shaanxi, Jilin, Anhui, Yunnan, Heilongjiang, Ningxia, Fujian, Jiangsu, Guangxi, Gansu, Guizhou, Shandong, Jiangxi, Shanxi, Hebei, Inner Mongolia, Hunan, Zhejiang, Sichuan, Liaoning, and Henan. In Beijing, Shanghai, Tianjin, and Chongqing, the data of some districts and counties are missing, so they are excluded. Qinghai, Xinjiang, and Tibet were excluded due to the lack of city-level data. Hainan, which lacks a prefecture-level administrative tier, is excluded. At the city level, to avoid bias from administrative changes, cities undergoing restructuring (e.g., district-to-city conversions) are excluded.

Variables	Bed_bc	Bed_bc	Doc_bc	Doc_bc
Year	**2010**	**2019**	**2010**	**2019**
Anhui	0.0795	0.0527	0.0458	0.0963
Fujian	0.0352	0.0166	0.0707	0.0888
Gansu	0.1286	0.0591	0.0692	0.1239
Guangdong	0.1988	0.1709	0.1972	0.2671
Guangxi	0.0423	0.0476	0.0593	0.0565
Guizhou	0.0992	0.0426	0.0932	0.2215
Hebei	0.0123	0.0065	0.0103	0.0206
Henan	0.0477	0.0813	0.0773	0.0327
Heilongjiang	0.0380	0.0144	0.0144	0.1115
Hubei	0.0685	0.0840	0.0601	0.0761
Hunan	0.0563	0.0339	0.0281	0.0497
Jilin	0.0296	0.0224	0.0079	0.0198
Jiangsu	0.0468	0.0535	0.0446	0.0704
Jiangxi	0.0171	0.0197	0.0273	0.0310
Liaoning	0.0315	0.0290	0.0413	0.0340
Inner Mongolia	0.0691	0.0366	0.0652	0.0281
Ningxia	0.0829	0.0784	0.1032	0.0632
Shandong	0.0319	0.0284	0.0334	0.0456
Shaanxi	0.0310	0.0706	0.0663	0.0570
Shanxi	0.0247	0.0218	0.0465	0.0170
Sichuan	0.0588	0.0370	0.0960	0.0865
Yunnan	0.0720	0.0787	0.1557	0.4032
Zhejiang	0.0306	0.0410	0.0299	0.0195

Table 2. Theil index.

Conversely, provinces like Henan (beds, from 0.0477 to 0.0813) experienced growing disparities in medical material resources. Yunnan (doctors, from 0.1557 to 0.4032) and Gansu (doctors, from 0.0692 to 0.1239) witnessed substantial increased disparities in medical human resources. These findings on the equalization level of medical resources within provinces calculated by the Theil index are comparable to previous studies[2,12,37].

Benchmark analysis

Table 3 reports the estimation results of Eq. (2), in which models (1) and (3) control the year and province fixed-effect, and models (2) and (4) report the estimation results after adding control variables. The estimation results of models (1) and (2) show that the estimation coefficients of dependent variables to Bed_bc are negative at the 5% significance level and negative at the 1% significance level after adding control variables. The value of the Theil index ranges from 0 to 1, and the closer it is to 0, the higher the level of equalization between cities in the province is. The estimated result of model (2) shows that the Theil index has dropped by 0.009 on average, which indicates that the implementation of the HMS has promoted the equalization of medical material resources between cities in the province. Based on the average value of the Theil index of 2012, the decreases are about 18.5%. The estimated results of models (3) and (4) are negative but not significant, which indicates that

	(1)	(2)	(3)	(4)
	Bed_bc		***Doc_bc***	
HMS	− 0.0095**	− 0.0090***	− 0.0099	− 0.0114
	(0.0035)	(0.0031)	(0.0066)	(0.0070)
Control variables	No	Yes	No	Yes
Year FE	Yes	Yes	Yes	Yes
Province FE	Yes	Yes	Yes	Yes
Observations	230	230	230	230
R^2	0.255	0.318	0.087	0.183

Table 3. Effect of the HMS on the equalization between cities. Cluster robust standard error in parenthesis. The significance levels of 1%, 5%, and 10% are denoted by ***, **, and *, respectively. All regressions control for year FE, province FE.

	(1)	(2)
	Bed_bc	***Doc_bc***
HMS	− 0.0086***	− 0.0110
	(0.0030)	(0.0082)
Control variables	Yes	Yes
Observations	230	230
LR test	168.53	83.71

Table 4. The results of Tobit model. Standard error in parenthesis. The significance levels of 1%, 5%, and 10% are denoted by ***, **, and *, respectively. The null hypothesis of LR test is "there is no individual effect", which is strongly rejected here, so the random effect model is chosen. All regressions control for province-by-year covariates.

the implementation of the HMS may not significantly promote the equalization of medical human resources between cities in the province in the short term. Additionally, the Tobit model estimation results in Table 4 confirm the findings of TWFE. Hypothesis 1 is supported partially.

In the quest for equitable distribution of medical human resources, the immediate impact of policy changes is often less noticeable due to the complexities inherent in policy formulation and the supply dynamics of medical human resources. The HMS, acting as a strategic framework for talent distribution, places a strong emphasis on nurturing medical personnel at the grassroots level by offering a comprehensive range of support measures, including training opportunities, talent development programs, and expert guidance. However, the role of the HMS is more about fostering an environment that encourages long-term growth rather than providing immediate, tangible outcomes. Unlike the direct fiscal investment in physical resources, the enhancement of medical human resources at the grassroots level is a policy-driven process that requires time to bear fruit. Moreover, the regional mobility of healthcare workers is often constrained by factors such as income levels, personal preferences, and career advancement opportunities, which typically draw them toward more developed urban areas[38]. The absence of attractive incentives for working in underserved areas—characterized by inadequate compensation and limited opportunities for career progression—further discourages the redistribution of medical talent. Additionally, the concentration of medical educational resources in central cities exacerbates the maldistribution of skilled graduates, resulting in a bottleneck that hinders the supply of medical human resources to areas that are less developed. The high qualification thresholds of the medical profession, which mandate extensive education and rigorous certification processes, limit the influx of new professionals into the field. Furthermore, the extended training period, often spanning several years to a decade, delays the availability of qualified personnel to underserved regions.

Event Study

To test the above explanation further, we refer to the event study method and use Eq. (3) to estimate the dynamic effect of the implementation of the HMS on the equalization between cities in the province. Figure 2 reports the change of the coefficient of the variable according to Eq. (3) with time (confidence interval is 95%). The results show that for the Theil bed index, after the implementation of the HMS, it can respond immediately in the current period, and the level of equalization of medical material resources between cities in the province has been improved to a certain extent. This influence has been declining until the third year after the implementation of the policy and then is not significant. However, the Theil doctor index is not significant in the current period and the following year but has a certain degree of influence from the second year after its implementation, and it continues until the fourth year. It is further verified that compared with medical material resources, it might be difficult for medical human resources to adjust quickly to improve equalization levels within provinces.

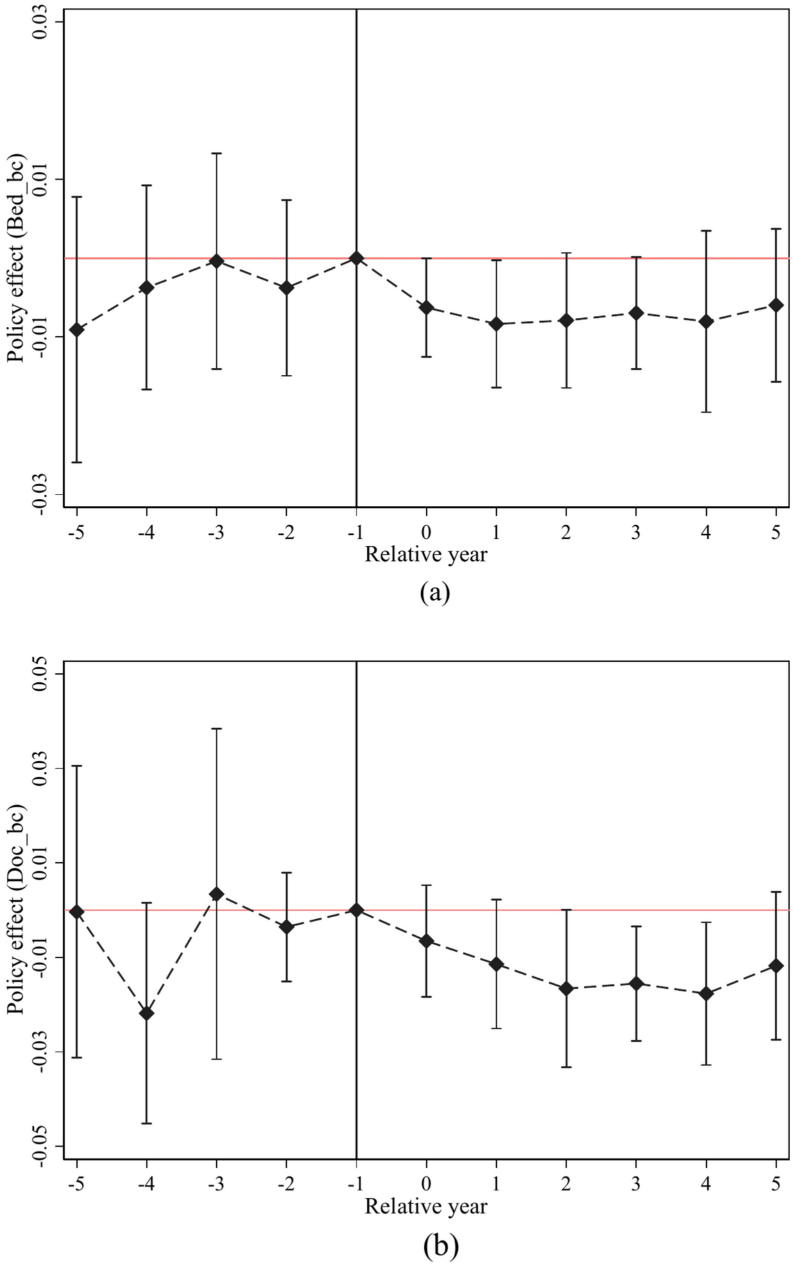

Fig. 2. Dynamic effects of the HMS on the equalization of medical resource supply.

Robustness tests

Parallel trend test

An important assumption of the DID method is that there is the common trend in the equalization indicators between the provinces (treatment group) that have implemented the HMS and the provinces (control group) that have not yet implemented the HMS. We can also employ Eq. (3) to test the common trend hypothesis. As shown in Fig. 2, the various independent variables before the implementation of the HMS do not exhibit statistical significance at the 5% significance level. This observation suggests that there is no substantial disparity in the equalization indicators, thus satisfying the assumption of the common trend.

Placebo test

To ensure that our method accurately captures the effect driven by the HMS rather than some confounders, we conduct two placebo tests. First, assuming that the HMS took place 2 years before the actual time point, observe whether the implementation of the virtual HMS still significantly impacts the relevant equalization indicators. If it is not significant, the influence of pre-event trends and confounders can be somewhat eliminated. The results are shown in Table 5, with no significant results. The placebo test once again provides evidence that

	(1) *Bed_bc*	(2) *Doc_bc*
HMS	−0.0004	0.0043
	(0.0032)	(0.0082)
Control variables	Yes	Yes
Year FE	Yes	Yes
Province FE	Yes	Yes
Observations	230	230
R^2	0.289	0.176

Table 5. Advance the implementation points of the HMS in each province by 2 years. Cluster robust standard error in parenthesis. The significance levels of 1%, 5%, and 10% are denoted by ***, **, and *, respectively. All regressions control for year FE, province FE and province-by-year covariates.

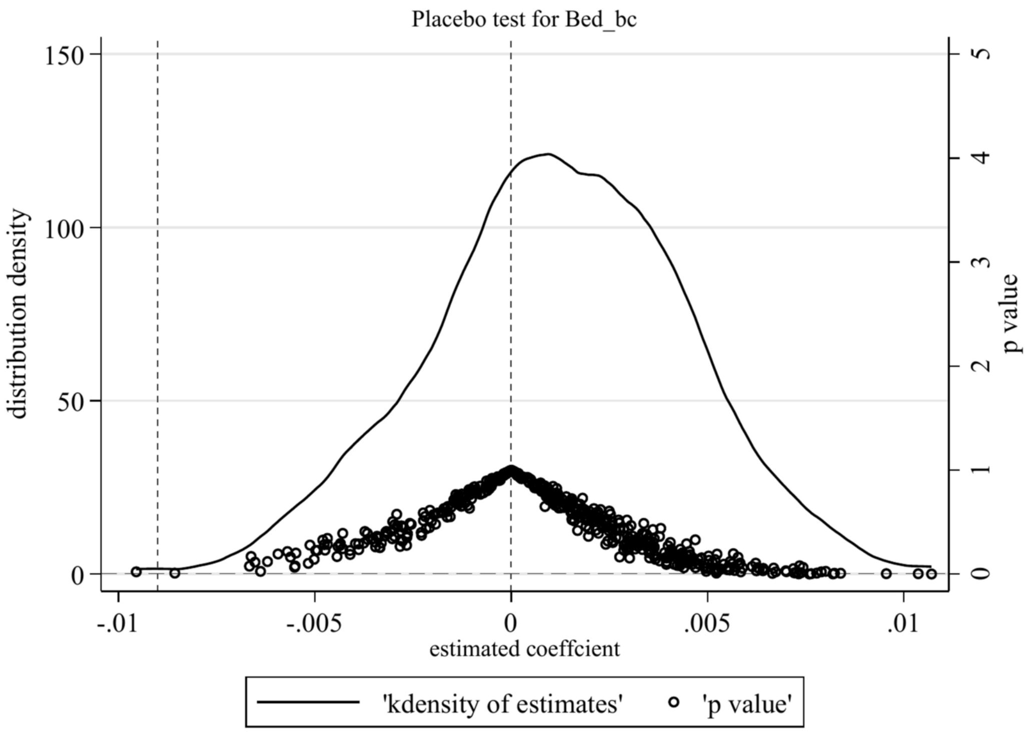

Fig. 3. Placebo test. This figure depicts the distribution of estimated coefficients and corresponding *p* values for 500 pseudo-treated samples. The X-axis depicts the estimated pseudo-treated coefficients. The Y-axis depicts the distribution density and *p* values. The vertical dashed line depicts the actual treated effect of −0.009 for Bed_bc. The horizontal dashed line depicts the 10% significant level. As illustrated in the figure, the estimated coefficients are predominantly near zero, and the majority of estimated values have *p* values greater than 0.1 (not significant at the 10% level).

the significance of relevant indicators of equalization is not due to the influence of pre-event trends or other accompanying policies.

Second, we give each province a pseudo-treated year when the HMS began, which is randomly selected, instead of the actual year. The regression coefficients are estimated repeatedly 500 times. The placebo plot in Fig. 3 demonstrates that the average value of the estimated coefficients for 500 regressions is close to 0. In contrast, the coefficient in the baseline regression model, denoted by the dotted line on the left, is statistically significant and deviates from the placebo coefficients. The placebo test verifies that the results of the baseline regression model are not due to unobserved confounder factors.

Measurement of equalization

To avoid the error caused by a single equalization index measurement, the Theil-L index and coefficient of variation (CV) are further considered to replace the explained variables for the baseline regression model. The Theil-L index, weighted by population proportion, is more sensitive to the change of lower resources, and the calculation method of Eq. (4) is adopted.

	(1)	(2)	(3)	(4)
	CV		Theil-L	
	Bed_bc	*Doc_bc*	*Bed_bc*	*Doc_bc*
HMS	−0.0251**	−0.0236	−0.0076**	−0.0111
	(0.0091)	(0.0149)	(0.0029)	(0.0065)
Control variables	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Province FE	Yes	Yes	Yes	Yes
Observations	230	230	230	230
R^2	0.312	0.180	0.319	0.192

Table 6. Different equalization indicators. Cluster robust standard error in parenthesis. The significance levels of 1%, 5%, and 10% are denoted by ***, **, and *, respectively. All regressions control for year FE, province FE and province-by-year covariates.

	(1)	(2)	(3)	(4)
	Bed_bc		*Doc_bc*	
	High supply	Low supply	High supply	Low supply
HMS	−0.0184**	−0.0025	−0.0103*	0.0036
	(0.0059)	(0.0035)	(0.0047)	(0.0099)
Control variables	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Province FE	Yes	Yes	Yes	Yes
Observations	110	120	110	120
R^2	0.311	0.451	0.236	0.381

Table 7. The impact of the HMS on the equalization between cities (high supply vs. low supply). Cluster robust standard error in parenthesis. The significance levels of 1%, 5%, and 10% are denoted by ***, **, and *, respectively. All regressions control for year FE, province FE and province-by-year covariates. The Chow test statistics between high and low supply groups of Bed_bc and Doc_bc are significant at 15% significance level, which indicates that there are significant differences in coefficients between groups.

$$Theil_i^L = \sum_j^N \left(\frac{P_{ij}}{P_i}\right) \log\left(\frac{P_{ij}}{P_i} \Big/ \frac{Y_{ij}}{Y_i}\right) \tag{4}$$

where Y_{ij} denotes the medical resource supply of the city j in the province i, and Y_i denotes the medical resource supply of the province i. P_{ij} is the population of the city j in the province i, and P_i is the population of the province i.

However, the Theil-T and Theil-L indices are sensitive to changes in the upper and lower layers, but insensitive to changes in the middle level. The CV can compensate for this issue. CV is used to calculate the equalization as follows.

$$CV_i = \frac{\sigma_i}{\mu_i} \tag{5}$$

where σ_i denotes the variance of medical resources between cities in the province i. μ_i is the average level of medical resources supply in the province i.

The results of Theil-L and CV are consistent with the baseline results (Table 6).

Factors influencing the equalization effect

Supply abundance

We analyze the impact of the supply level of medical resources on equalization between cities in the province. We take 2012, the earliest implementation of the HMS, as the baseline year. According to the median of the number of beds and doctors per 1000 people, two sub-samples with high and low relative supply are generated. The results (Table 7) show that after the implementation of the HMS in provinces with high material resources and high human supply levels, the effect of equalization is significant. In contrast, that in provinces with low material resources and low human supply levels is not significant. The coefficient differences of policy effect are 0.0159 and 0.0139, respectively. The coefficient differences between groups are significant, indicating that the HMS has the stronger equalization effect in the province with the high supply level. Thus, Hypothesis 2 is supported.

	(1)	(2)	(3)	(4)
	Bed_bc		*Doc_bc*	
	High demand	Low demand	High demand	Low demand
HMS	−0.0123***	−0.0053	−0.0177	−0.0073
	(0.0031)	(0.0050)	(0.0129)	(0.0064)
Control variables	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Province FE	Yes	Yes	Yes	Yes
Observations	110	120	110	120
R^2	0.483	0.315	0.226	0.272

Table 8. Effect of the HMS on the equalization between cities (high demand vs. low demand). Cluster robust standard error in parenthesis. The significance levels of 1%, 5%, and 10% are denoted by ***, **, and *, respectively. All regressions control for year FE, province FE and province-by-year covariates. The Chow test statistic between high and low supply groups of Bed_bc is significant at the 10% significance level, which indicates that there are significant differences in the coefficients between the groups.

	(1)	(2)	(3)	(4)
	Bed_bc		*Doc_bc*	
	Unbalanced	Balanced	Unbalanced	Balanced
HMS	−0.0130***	−0.0035	−0.0314**	−0.0003
	(0.0037)	(0.0027)	(0.0133)	(0.0038)
Control variables	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Province FE	Yes	Yes	Yes	Yes
Observations	110	120	110	120
R^2	0.492	0.236	0.358	0.146

Table 9. Effect of the HMS on the equalization between cities (economic imbalance vs. economic balance). Cluster robust standard error in parenthesis. The significance levels of 1%, 5%, and 10% are denoted by ***, **, and *, respectively. All regressions control for year FE, province FE and province-by-year covariates. The Chow test statistics between the high and low supply groups of Bed_bc and Doc_bc are significant at the 10% significance level, which indicates that there are significant differences in the coefficients between the groups.

Demand intensity

According to the calculation method of the China Health Statistical Yearbook, Daily Visits Per Doctor in Hospital is equal to the number of visits per year divided by the average number of doctors and then divided by 251 (the number of working days per year). According to the affiliation of the health department, the general hospitals are divided into five levels: hospital of the National Health Commission, province hospital, hospital of the city at the prefecture, hospital of the city at the country level, and country hospital. Hospitals with higher affiliated levels usually have higher medical quality. Therefore, we employ the ratio of the Daily Visits Per Doctor of provincial hospitals to the Daily Visits Per Doctor of county hospitals to measure the demand for high-level hospitals. We also take 2012, the earliest implementation of the HMS, as the baseline year. The results (Table 8) show that after the implementation of the HMS in provinces with the higher demand for high-level hospitals, the effect of equalization is more significant. Hypothesis 3 is supported.

Economic imbalance

We further investigate the impact of the HMS on the equalization between cities in provinces with unbalanced economies. Similarly, 2012, the first year of the HMS, is taken as the baseline year, and two sub-samples of relative economic imbalance and relative economic balance were generated according to the median of the index of economic imbalance (*TGDP*) between cities in the province. According to the baseline regression model, get the regression results in Table 9. The results show that the coefficient differences of policy effects are 0.0095 and 0.0311, respectively, and there are significant differences between groups. Hypothesis 4 is supported.

Conclusion and discussion

This study is, to our knowledge, the first to examine the impact of the HMS on the supply side of medical resources at the provincial level. Our empirical analysis revealed that the HMS has significantly contributed to the equalization of medical material resources within provinces. However, it has not significantly affected the equalization of medical human resources. The robustness of our results was confirmed through parallel trend tests, placebo tests, and the substitution of different equalization measures. At the micro-level, Lu et al.[22]

conducted an analysis focused on Beijing, assessing the equity and accessibility of medical resources before and after the HMS using a three-stage two-step floating catchment area method. Their findings indicated that the HMS exacerbated the inequality of resource accessibility among towns and streets. However, our study takes a macro perspective to analyze intra-provincial disparities in medical resource distribution across the country. Although our conclusion is not comparable to the findings of Lu et al.[22], our study contributes to the existing literature by providing insights into the broader implications of the HMS on resource distribution. Anand et al. have shown that the inequality in doctor distribution is significant, primarily due to within-province disparities rather than between-province differences, which greatly impacts health outcome inequalities[9]. Our findings reveal the limited effect of the implementation of the HMS on the equalization of medical human resources within provinces. A plausible explanation is that transferring funds from developed regions and investing in material resources in underdeveloped areas is relatively straightforward, which promotes medical material resource equalization[39]. In contrast, the supply of human resources is influenced by various factors, such as revenue, the economic status of the cities, the limitations of medical staff's professional qualifications, lengthy training periods, and hospital personnel turnover, which often fail to rapidly enhance the supply level in underdeveloped areas[40,41]. Consequently, it is still challenging for the HMS to promote the equalization of medical human resources among cities. A study from Shanghai has also revealed that while there has been an improvement in medical material resources, disparities among doctors persist, indicating that the recruitment and education of healthcare personnel is an ongoing endeavor necessary to bridge the gap in medical resource distribution between center city and sub-city[42].

We found that in the provinces with higher levels of medical resource supply, the HMS's effect on promoting equalization was more significant. Previous studies suggest that a higher supply of overall medical service resources may indicate that the government is capable of allocating medical resources to underdeveloped areas[2,37]. In terms of hospital size regulation, in provinces where medical resources are abundant and overly concentrated, the HMS may exert a stronger influence in guiding and encouraging medical institutions to plan their scale rationally and prevent indiscriminate expansion. Additionally, the HMS's impact on promoting the equalization of medical resources is more pronounced in areas with a higher demand for high-level hospitals. The medical demand-side pressures suggest a stronger HMS reform motivation in provinces with higher demand for high-level medical resources. Our findings provide suggestive evidence that demand-side factors might drive the HMS reform on the supply side.

Moreover, the HMS promoted equalizing medical resources in provinces with relatively unbalanced economic development. Economic development is the primary material guarantee for providing medical services. In the process of economic development, where economic factors are concentrated, medical resources are also highly concentrated in space, which leads to regional inequality of medical resources. Implementing the HMS promoted equalizing medical resource supply in provinces with unbalanced economic development, which reflects the characteristics of the HMS promoting fairness. An effective strategy to reduce medical resource inequality involves creating a flexible tax-sharing framework, which helps balance local governments' fiscal capacities, providing those with lower self-sufficiency access to additional financial resources[29]. Decentralization encompasses several dimensions: policy, political, and fiscal[43,44]. Concurrently, the promotion of medical resource equity through the HMS has been accompanied by a redistribution of financial responsibilities. The central government requires provincial governments to further rationalize the financial affairs and expenditure responsibilities of sub-provincial governments within the medical and health sector. The responsibilities of provincial governments in advancing the equalization of medical services have been clarified, and transfer payments to underprivileged areas within the region have been increased. The HMS facilitates the transfer of basic medical and health service expenditure responsibilities to higher levels of government where appropriate, thereby preventing an excessive burden on grassroots government expenditures.

A significant policy implication arising from this study, and a key direction for future research, is the need to enhance the effectiveness of HMS policies in promoting a more equitable distribution of medical human resources. These resources are crucial for the operational framework of medical institutions and are a key determinant of their ability to deliver healthcare services. Our findings suggest that future HMS policies should prioritize strategies to redirect medical human resources toward less developed areas. Future research adopting a micro-level approach, by focusing on individual physicians, could provide valuable insights into how to achieve a more balanced distribution of medical human resources. An in-depth exploration of personal preferences, career aspirations, and the specific push-pull factors influencing the geographic distribution of medical professionals could significantly enhance our understanding of this complex phenomenon.

With the rapid development of information and communication technology (ICT), digital health technologies such as remote healthcare have been rapidly disseminated worldwide. These technologies not only enhance the accessibility and quality of medical services but also play a significant role in optimizing the allocation of medical resources and promoting healthcare equity. Future research can systematically analyze the mechanisms and equity effects of remote healthcare and other information technologies in promoting the equal distribution of medical resources from a spatial equity perspective. It is important to explore the role of digital health technologies in reducing patient mobility across regions, shortening medical consultation times, and lowering healthcare costs, as well as its potential to enhance healthcare equity for vulnerable groups, such as the older people and people with disabilities.

This study had several potential limitations. First, due to the limitation of sample size, there is only one province that has never been treated during the sample period. Because of the heterogeneous treatment effect, our estimate of TWFE may be biased[45,46]. Second, due to data limitations at the city level, we measure medical human and material resources solely by the number of doctors and beds, respectively, which may not represent the reality of resource distribution. We were only able to measure the equalization of medical resources among cities within the province, without being able to analyze it at a more granular district level. This restriction limited our ability to capture potential variations and nuances within the province. Third, it is worth noting that the quality of the medical resource supply is also an important aspect deserving consideration. However, this paper focuses solely on quantity due to the challenge of measuring the distribution of medical quality within provinces. Fourth, the influencing factors of macro-level changes in the context of medical resource equalization are inherently complex. Therefore, the evidence presented in this study regarding the underlying factors is suggestive. In future research, gathering micro-level evidence and conducting more detailed investigations would be valuable.

To sum up, this study provided empirical evidence of the impact of the HMS on medical resource allocation. These findings have important policy implications, particularly for addressing the unequal medical resource allocation in China. The role of the government in achieving equal access to medical services is a crucial topic in health economics and public management. The study's findings and the policy practices in China have the potential to promote the realization of universal health coverage.

Data availability

The main data used in this study are publicly available and were obtained from the National Bureau of Statistics of the People's Republic of China website (http://www.stats.gov.cn/). Policy data are from public websites, including the official health department sites of various Chinese provinces and Peking University Law's Local Laws and Regulations Database (https://www.pkulaw.com/).

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References

1. Chai, K.-C. et al. The structural characteristics of economic network and efficiency of health care in China. *Front. Public Health* **9**, 724736 (2021).
2. Wan, S. et al. Spatial analysis and evaluation of medical resource allocation in China based on geographic big data. *BMC Health Serv. Res.* **21**, 1084 (2021).
3. Fu, L., Xu, K., Liu, F., Liang, L. & Wang, Z. Regional disparity and patients mobility: Benefits and spillover effects of the spatial network structure of the health services in China. *Int. J. Environ. Res. Public Health* **18**(3), 1096 (2021).
4. Yan, X., Shan, L., He, S. & Zhang, J. Cross-city patient mobility and healthcare equity and efficiency: Evidence from Hefei, China. *Travel Behav. Soc.* **28**, 1–12 (2022).
5. Deng, Z., Jiang, N., Song, S. & Pang, R. Misallocation and price distortions: A revenue decomposition of medical service providers in China. *China Econ. Rev.* **65**, 101574 (2021).
6. Fang, Y., Fu, L., Xu, Y. & Dong, Y. The divergence of inequality in healthcare utilization between poor- and rich-medical resource regions: Evidence from the middle-aged and older adults in China. *Soc. Indic. Res.* **17**, 347-369 (2024).
7. Su, B. et al. The effect of equalization of public health services on the health China's migrant population: Evidence from 2018 China migrants dynamic survey. *Front. Public Health* **10**, 1043072 (2023).
8. Chai, K.-C., Zhang, Y.-B. & Chang, K.-C. Regional disparity of medical resources and its effect on mortality rates in China. *Front. Public Health* **8**, 8 (2020).
9. Anand, S. et al. China's human resources for health: Quantity, quality, and distribution. *Lancet* **372**(9651), 1774–1781 (2008).
10. Horev, T., Pesis-Katz, I. & Mukamel, D. B. Trends in geographic disparities in allocation of health care resources in the US. *Health Policy* **68**(2), 223–232 (2004).
11. Pan, J. & Chen, C. Reducing universal health coverage regional disparities in China. *Lancet Public Health* **7**(12), e985–e986 (2022).
12. Lu, L. & Zeng, J. Inequalities in the geographic distribution of hospital beds and doctors in traditional Chinese medicine from 2004 to 2014. *Int. J. Equity Health* **17**(1), 165 (2018).
13. Council, C. C. P. C. A. S. *Opinions on Deepening the Health Care System Reform (In Chinese)*. (2009).
14. Yip, W. et al. 10 years of health-care reform in China: progress and gaps in Universal Health Coverage. *Lancet* **394**(10204), 1192–1204 (2019).
15. Li, L. & Fu, H. China's health care system reform: progress and prospects. *Int. J. Health Plan. Manag.* **32**(3), 240–253 (2017).
16. Luo, D. et al. Healthcare preferences of chronic disease patients under China's hierarchical medical system: An empirical study of Tianjin's reform practice. *Sci. Rep.* **14**(1), 11631 (2024).
17. Zhou, Z. et al. Evaluating the effect of hierarchical medical system on health seeking behavior: A difference-in-differences analysis in China. *Soc. Sci. Med.* **268**, 113372 (2021).
18. Shen, X., Yang, W. & Sun, S. Analysis of the impact of China's hierarchical medical system and online appointment diagnosis system on the sustainable development of public health: A case study of Shanghai. *Sustainability* **11**(23), 6564 (2019).
19. Hu, H. et al. Effectiveness of hierarchical medical system policy: An interrupted time series analysis of a pilot scheme in China. *Health Policy Plan.* **38**(5), 609–619 (2023).
20. Liang, C., Zhao, Y., Yu, C., Sang, P. & Yang, L. Hierarchical medical system and local medical performance: A quasi-natural experiment evaluation in Shanghai, China. *Front. Public Health* **10**, 904384 (2022).
21. Wu, Q., Xie, X., Liu, W. & Wu, Y. Implementation efficiency of the hierarchical diagnosis and treatment system in China: A case study of primary medical and health institutions in Fujian province. *Int. J. Health Plan. Manag.* **37**(1), 214–227 (2022).
22. Lu, C., Zhang, Z. & Lan, X. Impact of China's referral reform on the equity and spatial accessibility of healthcare resources: A case study of Beijing. *Soc. Sci. Med.* **235**, 112386 (2019).
23. Baeten, S., Ourti, T. V. & Doorslaer, E. V. Rising inequalities in income and health in China: Who is left behind? *J. Health Econ.* **32**, 1214–1229 (2013).
24. Zhao, Z. Income inequality, unequal health care access, and mortality in China. *Popul. Dev. Rev.* **32**(2), 461–483 (2006).
25. Council, G. O. O. T. S. *Guiding Opinions on Promoting the Construction of Hierarchical Medical System (In Chinese)*. (2015).
26. Fu, L., Dong, Y. & Wang, R. Research on the cooperativity of Chinese hierarchical medical system policy: Based on quantitative analysis of central and provincial policy texts (In Chinese). *Public Administration and Policy Review* **14**(1), 4-24 (2025).
27. Hou, Y., Tao, W., Hou, S. & Li, W. Levels, trends, and determinants of effectiveness on the hierarchical medical system in China: Data envelopment analysis and bootstrapping truncated regression analysis. *Front. Public Health* **10**, 921303 (2022).
28. Lan, T., Chen, T., Hu, Y., Yang, Y. & Pan, J. Governmental investments in hospital infrastructure among regions and its efficiency in China: An assessment of building construction. *Front. Public Health* **9**, 719839 (2021).
29. Chen, T., Wang, Y., Luo, X., Rao, Y. & Hua, L. Inter-provincial inequality of public health services in China: The perspective of local officials' behavior. *Int. J. Equity Health* **17**, 108 (2018).
30. National Bureau of Statistics of China. *Interpretation of Main Statistical Indicators of the National Bureau of Statistics*. https://www.stats.gov.cn/zt_18555/ztsj/hstjnj/sh2009/202303/t20230303_1926973.html.

31. Liu, Y., Kong, Q., Yuan, S. & Klundert, V. D. J. Factors influencing choice of health system access level in China: A systematic review. *PLoS ONE* **13**(8), e0201887 (2018).
32. Wang, X., Zhu, Y., Liu, J., Ma, Y. & Birch, S. Equity in maternal and child health care utilization in Guangdong province of China 2009–2019: A retrospective analysis. *Front. Public Health* **10**, 963344 (2022).
33. Beck, T., Levine, R. & Levkov, A. Big bad banks? The winners and losers from bank deregulation in the United States. *J. Finance* **65**(5), 1637–1667 (2010).
34. Liu, H., Fang, C. & Fan, Y. Mapping the inequalities of medical resource provision in China. *Reg. Stud. Reg. Sci.* **7**(1), 568–570 (2020).
35. Novi, D. C., Kovacic, M. & Orso, C. E. Online health information seeking behavior, healthcare access, and health status during exceptional times. *J. Econ. Behav. Organ.* **220**, 675–690 (2024).
36. Zhang, D. et al. Online health information-seeking behaviors and skills of Chinese college students. *BMC Public Health* **21**, 736 (2021).
37. Yuan, L. et al. Regional disparities and influencing factors of high quality medical resources distribution in China. *Int. J. Equity Health* **22**(1), 8 (2023).
38. Fang, P., Liu, X., Huang, L., Zhang, X. & Fang, Z. Factors that influence the turnover intention of Chinese village doctors based on the investigation results of Xiangyang City in Hubei Province. *Int. J. Equity Health* **13**, 84 (2014).
39. Zhou, M. Equity and efficiency of health resource allocation in Sichuan Province, China. *BMC Health Serv. Res.* **24**, 1439 (2024).
40. Li, D. et al. Unequal distribution of health human resource in mainland China: What are the determinants from a comprehensive perspective? *Int. J. Equity Health* **17**, 29 (2018).
41. Nasiri, A., Yusefzadeh, H., Amerzadeh, M., Moosavi, S. & Kalhor, R. Measuring inequality in the distribution of health human resources using the Hirschman-Herfindahl index: A case study of Qazvin Province. *BMC Health Serv. Res.* **22**, 1161 (2022).
42. Dong, E. et al. Differences in regional distribution and inequality in health-resource allocation on institutions, beds, and workforce: A longitudinal study in China. *Arch. Public Health* **79**, 78 (2021).
43. Resce, G. The impact of political and non-political officials on the financial management of local governments. *J. Policy Model.* **44**(5), 943–962 (2022).
44. Rodden, J. Comparative federalism and decentralization: on meaning and measurement. *Comp. Polit.* **36**(4), 481–500 (2004).
45. Goodman-Bacon, A. Difference-in-differences with variation in treatment timing. *J. Econom.* **225**(2), 254–277 (2021).
46. Fu, L., Wang, R. & He C. Gender differences in later life: Labor supply responses to spousal disability. *Soc. Sci. Med.* **366**, 117638 (2025).

Author contributions

L.F.: Supervision, conceptualization, funding acquisition, writing-review and editing, methodology. R.W.: Writing-original draft, formal analysis. Y.D.: Data collection, writing-original draft. All authors have read and agreed to the published version of the manuscript.

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Declarations

Competing interests

The authors declare no competing interests.

Additional information

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